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(54) **Display device.**

(57) In a flat display device, for example, a luminescent display a spacer structure (5) is provided between two substrates (1, 3). To this end a mask (9, 15) consisting, if necessary, of a plurality of layers is incorporated in a photosensitive material (8,13). After exposure, development and removal of the mask, the desired spacer structure is obtained.

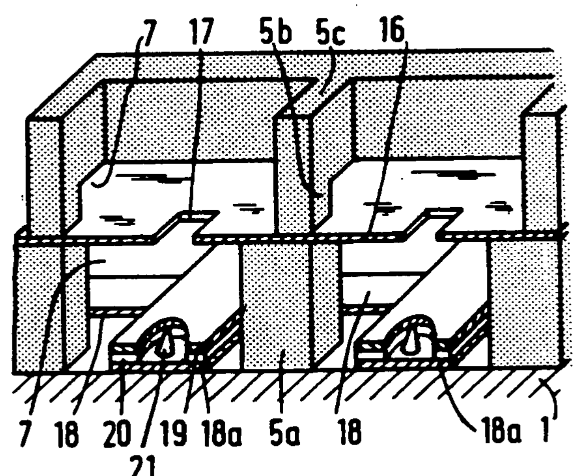

FIG. 11

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The invention relates to a display device comprising a first substrate, at least one electron source and a second substrate spaced apart from the first substrate by at least one spacer made of an organic polymer.

The invention also relates to a method of manufacturing such a display device.

Flat display devices of this type are used as display panels in, for example, portable computers, but also at other places where the use of cathode ray tubes may give rise to problems. Moreover, there is an increasing interest in flat display devices for video applications.

A display device of the type mentioned above is described in PCT/WO-90/00808. Spacers made of polyimide are shown in the device described in this document. These spacers are manufactured by coating a substrate with a layer comprising a polyamide ester, by subsequently drying this layer and patterning it photolithographically. After exposure by ultraviolet radiation, development and further treatment, polyimide spacers having a height of 100 to 150 µm are obtained in this way.

However, the display device shown has a number of drawbacks. For example, the front side of such a panel must be provided with phosphors which in their turn are coated with a conducting layer of, for example, aluminium or provided on a layer of indium-tin oxide for the purpose of transporting electrons. To obtain a satisfactory display, notably in television applications, an accelerating voltage of the order of 2 to 5 kV is required (dependent on the materials used, gas filling, etc.) between the first substrate (where electron sources in the form of field emitters are present in said device) and the second substrate. In the device according to PCT/WO-90/00808 the spacers consist of an organic chemical material (polyimide). At said high accelerating voltages this may lead to graphite formation *via* flash-over so that both the vacuum and the electrical behaviour of the device may be influenced detrimentally. Though it is possible to prevent this by providing the spacers with a suitable coating (for example, chromium oxide or silicon oxide), this requires additional process steps such as vapour deposition while simultaneously rotating the substrate, or preferential precipitation from a liquid, but on the other hand the substrate must usually be protected against this treatment.

Another drawback of the device shown in PCT/WO-90/00808 is that due to backscattering of electrons or secondary emission an adjacent pixel may be excited by these backscattered or secondary electrons.

One of the objects of the present invention is to provide a display device of the type described hereinbefore in which high accelerating voltages can be used without said graphite formation or other problems occurring due to a too high field strength. It is another object of the invention to provide a display device in which said problems due to backscattering or secondary emission do not occur.

It is a further object of the invention to provide a method of manufacturing a display device having two substantially parallel substrates.

The invention is based on the recognition that this can be achieved, *inter alia,* by a cumulative effect of steps as described hereinbefore without each time repeating each step completely. It is further based on the recognition that, viewed in a cross-section, this repetitive treatment produces spacers at different levels with different cross-sections.

A display device according to the invention is therefore characterized in that the distance between the two substrates is at least 200 µm.

Since in this way the field strength may be smaller than in said devices while using the same accelerating voltage, the risks of forming graphite and influencing the vacuum are reduced considerably. It appears that spacers up to a height of approximately 1 mm can be realised in this way, with a surface of the cross-section at the area of the first substrate (where this surface is usually smallest due to the method used) of between 100 and 10,000 μm^2, while in this type of display devices the pitch between the pixels is generally of the order of 50 to 500 µm.

A first preferred embodiment of a display device according to the invention is characterized in that cross-sections of the spacer, viewed at different heights of the spacers, have different patterns.

It can thereby be achieved, for example, that viewed in a cross-section the spacer (which consists of, for example polyimide) forms a closed structure around a pixel at least at the area of the second substrate. This may be a rectangular structure, but it is preferably honeycomb-shaped. The closed structure at the location of the pixels prevents scattering of electrons to adjacent pixels.

If the display mechanism is based on the excitation of phosphors by means of electrons as described in PCT/WO-90/00808, the first substrate comprises, for example, a matrix of electron sources such as field emitters; alternatively, each electron source may be built up of a plurality of field emitters or, if the first substrate is a semiconductor, it may be integrated in this semiconductor body.

Another preferred embodiment of a display device according to the invention is characterized in that a spacer is intersected by at least one layer of conducting material.

In this way acceleration grids can be integrated in the spacers, for example, by providing structured

metal layers.

A method according to the invention is characterized in that a layer of patternable organic material having a thickness of at least 200 µm is provided on a substrate in which at least one spacer is defined photolithographically.

The layer is preferably provided by means of sub-layers in which, if necessary, auxiliary masks are provided photolithographically between two sub-layers, while in a plan view the auxiliary masks and the mask on the last-provided layer do not overlap each other or overlap each other only partially.

Alternatively, after at least one sub-layer has been provided, a part of the spacer can be defined in parts of the patternable material, whereafter this material is provided with a patterned layer of conducting material which in its turn is covered with at least one sub-layer for defining further parts of the spacer. In this way said integrated acceleration grids can be obtained.

These and other aspects of the invention will now be described in greater detail with reference to some embodiments and the drawing.

Fig. 1 is a diagrammatic representation of a part of a display device according to the invention.

Figs. 2 to 7 show diagrammatically the display device of Fig. 1, taken on the line II-II in Fig. 1, during several stages of manufacture.

Figs. 8 and 9 show diagrammatically the manufacture of another display device according to the invention.

Figs. 10 and 11 show the manufacture of a further device.

Fig. 12 shows diagrammatically a further display device according to the invention.

Fig. 1 shows a part of a display device according to the invention, comprising a first substrate of, for example, glass or silicon which is provided in this case with a matrix of electron sources 2 (for example, field emitters) which are manufactured in a manner known *per se*. The pixels 4 which in this example substantially coincide with phosphors provided at the side of the substrate 3 opposite the electron sources 2 are present opposite the electron sources on a second substrate 3 of glass. Although only two pixels 4 are shown, the device actually comprises at least 100,000 to 1,000,000 pixels, dependent on the type of device (monochrome, colour).

The substrates 1 and 2 are spaced apart by approximately 500 µm by means of spacers 5. In the relevant example these spacers comprise two parts, namely a first part 5a at the area of the first substrate 1 and a second part 5b at the area of the pixels 4 on the second substrate 3. The parts 5b may extend entirely around a pixel 4. The device shown is driven by causing electrons from the sources 2 to impinge upon the phosphors associated with the pixels 4. Backscattered electrons now impinge upon the parts 5b and thus cannot influence the adjacent pixels. Due to the large distance between the two substrates a comparatively high voltage difference can be applied therebetween (5-10 kV) without any danger of flash-over. The display device can be evacuated by means of the apertures 7 in the spacers 5.

The device of Fig. 1 may be manufactured as follows (see Figs. 2 to 7).

The manufacture starts from a first substrate 1, for example a semiconductor substrate (silicon or glass in this example) in which or on which electron sources (not shown) are realised, for example field emitters, but semiconductor cathodes as described in Netherlands Patent Application No. 7905470 (PHN 9532) in the name of the Applicant are also possible. A layer 8 of photosensitive polyamide acid or polyamide ester having a thickness of approximately 300 µm is provided on the substrate 1. A suitable polyamide ester is, for example Probimide 348 FC of the firm of Ciba-Geigy. Thin layers (up to approximately 100 µm) can be applied by means of a single spin-coating treatment of the polyamide ester. At the layer thickness used in this case, this polyamide ester is provided in accordance with the method as described with reference to Figs. 8 and 9 or with a suitable tool such as a "spacer knife". To protect the electron sources, a protective coating may be temporarily provided, if necessary.

The layer 8 is subsequently covered with a thin layer 9 (approximately 40 nm) of gold in this example on which a layer of positive photoresist 10 is provided. After exposure by means of ultraviolet radiation (shown diagrammatically by means of arrows 11) through a mask 12 which defines the apertures 7, and after development, the parts 10b are removed and the part 10a of the photoresist is left (Fig. 3). With the remaining photoresist as a mask the gold layer 9 is subsequently etched wet-chemically (Fig. 4) in an etchant suitable for this purpose (for example, an aqueous solution of 25% KI and 10% I_2). The structure thus produced is coated again with a photosensitive layer 13 of polyamide ester having a thickness of approximately 100 µm (Fig. 5). The assembly is subsequently exposed by means of ultraviolet and visible radiation (shown diagrammatically by means of arrows 14 in Fig. 6) *via* a mask 15 which defines the parts 5b of the spacers. The wavelength used and the duration of the exposure depend on the light intensity, the material used and the thickness of the layers 8, 13 (for a layer of Probimide 348, with a thickness of approximately 200 µm and exposure by means of the entire Hg spectrum the light intensity is, for example 15 mW/cm^2 for 200 sec-

onds). Since, in a plan view, there are open spaces between the auxiliary mask formed by the layers 9, 10a and the mask 15, the polyamide ester is cured throughout the thickness of the layers 8, 13 at these areas and these parts 5 are left on the subsequent substrate 1 in a subsequent development step. After cleaning, removal of the layers 9, 10a, possible further cleaning steps and a thermal post-treatment, the device of Fig. 7 is obtained.

The substrate 1 thus obtained, provided with emitting sources and spacers 5, is then laid on a second substrate 3 of, for example glass and provided with phosphors. After aligning the phosphors with respect to the electron sources, the assembly is sealed along the edges and evacuated. The device of Fig. 1 is then obtained.

Figs. 8 and 9 show how spacers having a height of 200 to 1000 µm can be obtained. The polyimide layer 8 is obtained by successively providing sub-layers 8a, 8b, 8c. Each subsequent sub-layer is not provided until the previous sub-layer has acquired a defined layer thickness (for example by means of spin-coating). Subsequently the locations of the spacers to be formed are defined *via* a mask 15 whereafter the assembly is exposed, developed, cured etc. The spacers 5 thus formed keep the two substrates 1, 3 of Fig. 9 spaced apart by, for example 450µm. In this example no auxiliary masks are used so that the spacers should have a uniform cross-section; in practice the cross-section at the area of the first substrate is usually slightly smaller because a negative photosensitive system is used and because there is light absorption in the layer.

Although a device is shown with an electron source for each pixel, the spacers may also be used in other flat display devices such as described in, for example, US-P-4,853,585 (PHN 12.047).

Fig. 10 shows the manufacture of another display device partly in a cross-section and partly in a plan view. The method starts again from a substrate 1, for example a glass plate on which a matrix of field emitters is provided. Sub-layers 8a, 8b of polyamide ester are deposited on the substrate 1 in the same way as described hereinbefore. By exposure with ultraviolet radiation cured areas 22 are formed in the sub-layers at the area of parts of the spacers to be formed. The layer thus formed is, however, not yet developed but first covered with a thin metal layer 16 having apertures 17 above the emitters. The metal layer 16 may be provided in advance with the apertures 17, but the pattern of apertures (or any other desired pattern) may also be provided after precipitation of the metal layer by means of etching. Subsequently a layer 8c of polyamide ester is again provided which in its turn is covered with a gold layer 9 patterned by means of etching. Subsequently a layer 13 of polyamide ester is provided whereafter the assembly is exposed with ultraviolet and/or visible radiation *via* a mask 15. After development, rinsing and possible further treatment, the device of Fig. 11 is obtained. This device has a substrate 1 on which square column-shaped parts 5a of the spacers are present in this example. The other parts of the spacers consist of similar column-shaped parts 5b and parts 5c which are closed along their circumference and which enclose pixels (phosphors) in the ultimate display device. The metal layer 16 which has apertures 17 at the location of field emitters 21 is present on the substrate 1 between the parts 5a and 5b of the spacers. The plate 16 may now function as a common accelerating electrode. To suppress possible backscattering to a further extent, the walls of the closed parts 5c may be coated with a conducting layer which is through-connected to the front plate 3 in, for example, an electrically conducting manner. This can also be achieved by providing a grid which is comparable with the metal layer 16 and by short-circuiting it electrically with the front plate 3.

Fig. 11 also shows diagrammatically two field emitters 21. In the present example they form part of a matrix of field emitters which are driven by X lines 18 and Y lines 19 and are mutually insulated by means of an insulation layer 20 at the area of their crossings where the X lines are provided with connection strips 18a. Apertures 7 providing the possibility of providing a vacuum during sealing are present between the parts 5a and between the parts 5b.

Finally, Fig. 12 shows a modification in which the closed parts 5b of the spacers have a honeycomb structure. Otherwise, the reference numerals denote the same elements as in the previous Figures. The exiting electron current is shown diagrammatically by means of arrows 23.

The invention is of course not limited to the examples shown, but several variations are possible within the scope of the invention. For example, the structure in which the spacers are defined can also be provided on the glass plate with phosphors instead of on the substrate 1. A plurality of metal masks may also be provided between the sub-layers so that, as it were, a part of the electron-optical system is integrated in the spacer(s).

Claims

1. A display device comprising a first substrate, at least one electron source and a second substrate spaced apart from the first substrate by at least one spacer made of an organic polymer, characterized in that the distance between the two substrates is at least 200 µm.

2. A display device as claimed in Claim 1, characterized in that the spacer at the area of the first substrate has the smallest surface of the cross-section parallel to the first substrate, which surface is at most 10,000 μm^2.

3. A display device as claimed in Claim 1 or 2, characterized in that cross-sections parallel to the first substrate of the spacer, viewed at different heights of the spacer, have different patterns.

4. A display device as claimed in Claim 3, characterized in that, viewed in a cross-section parallel to the substrate, the spacer forms a closed structure at the area of a substrate.

5. A display device as claimed in any one of the preceding Claims, characterized in that one of the substrates comprises a matrix of electron sources and in that the other substrate comprises a glass plate provided with one or more types of phosphors.

6. A display device as claimed in any one of Claims 1 to 5, characterized in that a spacer is intersected by at least one layer of conducting material.

7. A method of manufacturing a display device as claimed in any one of Claims 1 to 6, characterized in that a layer of patternable organic material having a thickness of at least 200 μm is provided on a substrate in which at least one spacer is defined photolithographically.

8. A method as claimed in Claim 7, characterized in that the layer is formed by successively providing a plurality of sub-layers in which at least the last-provided sub-layer is provided with a photolithographic mask for defining at least a part of the spacer.

9. A method as claimed in Claim 8, characterized in that at least one photolithographic auxiliary mask is provided between two sub-layers, while in a plan view the radiation-transmitting parts of the auxiliary mask and of the mask on the last-provided sub-layer do not overlap each other or overlap each other only partially.

10. A method as claimed in Claim 8 or 9, characterized in that after at least one sub-layer has been provided, a part of the spacer is defined in parts of the patternable material, whereafter this material is provided with a patterned layer of conducting material which in its turn is covered with at least one sub-layer for defining further parts of the spacer.

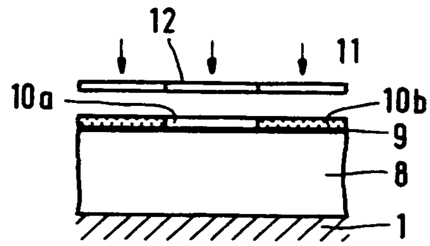

FIG.2

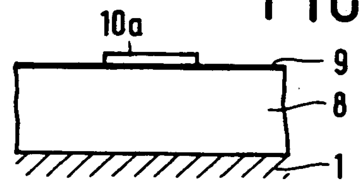

FIG.3

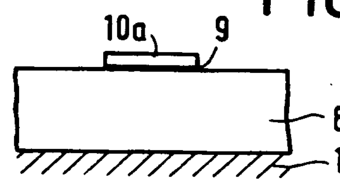

FIG.4

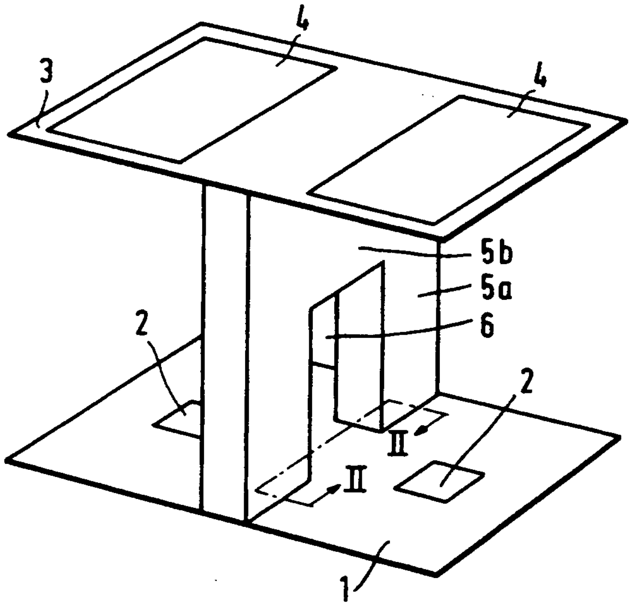

FIG.1

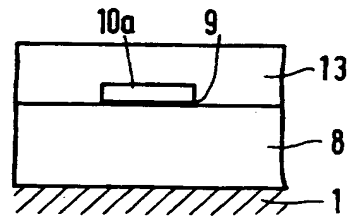

FIG.5

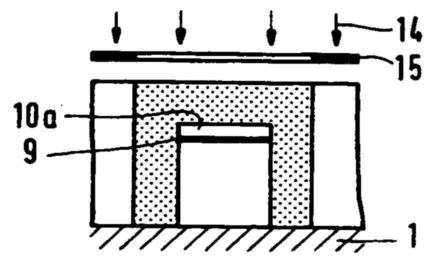

FIG.6

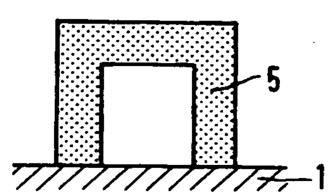

FIG.7

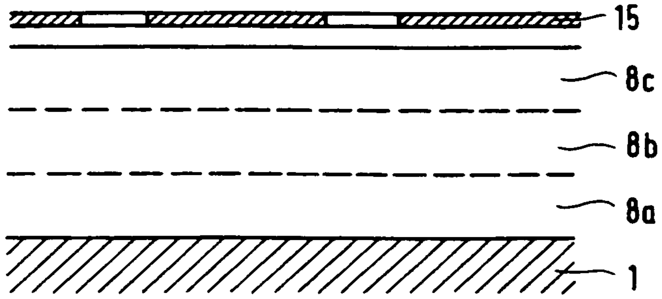

FIG.8

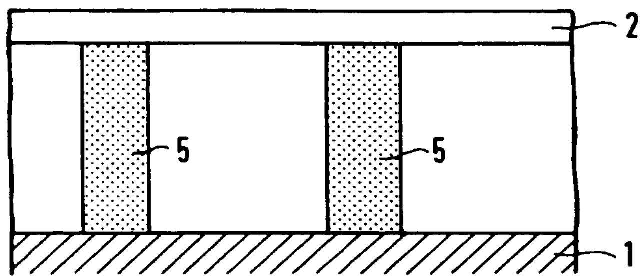

FIG.9

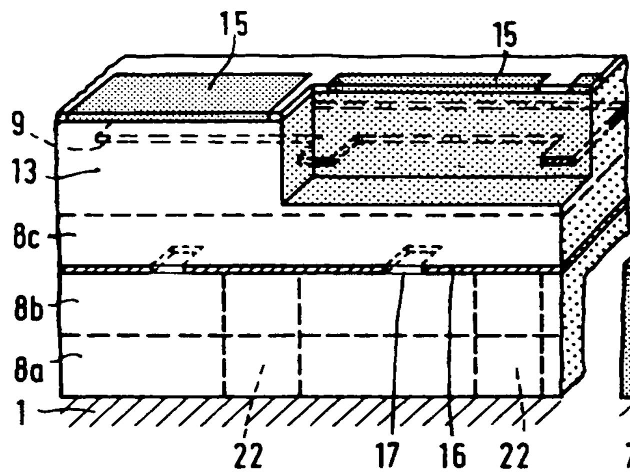

FIG.10

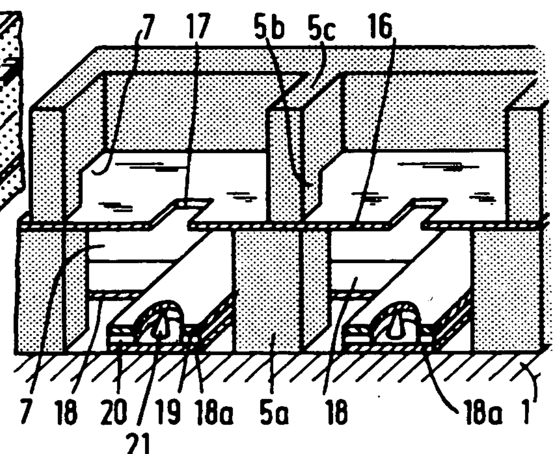

FIG.11

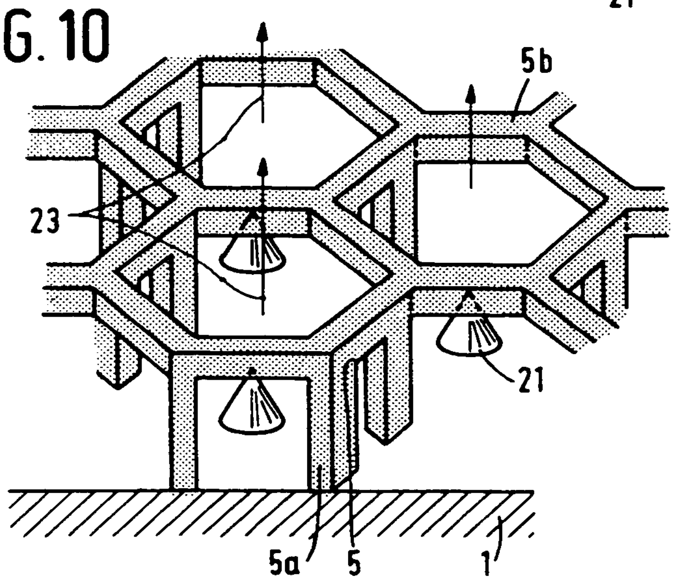

FIG.12

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EUROPEAN SEARCH REPORT

Application Number

EP 92 20 0108

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,Y A	WO-A-9 000 808 (INNOVATIVE DISPLAY DEVELOPMENT) * Abstract * * page 2, line 1 - page 5, line 26 * * page 11, line 17 - page 13, line 26 * * figures 4,5 *	1-6 7,8	H01J31/12 H01J9/18 H01J29/82
Y	EP-A-0 405 262 (MATSUSHITA) * Abstract * * column 1, line 17 - column 3, line 22 * * column 4, line 50 - column 5, line 58 * * column 9, line 29 - line 36 * * column 12, line 15 - line 32 * * figures 1-5,9,12 *	1-6	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 450 (E-830)(3798) 11 October 1989 & JP-A-01 175 146 (FUJITSU) 11 July 1989 * abstract *	1-5	
A	PATENT ABSTRACTS OF JAPAN vol. 14, no. 429 (E-978)(4372) 14 September 1990 & JP-A-02 165 540 (NARUMI CHINA CORP.) 26 June 1990 * abstract *	7,8	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	EP-A-0 404 022 (MATSUSHITA) * Abstract * * column 3, line 30 - column 4, line 9 * * column 11, line 2 - column 12, line 22 * * figures 9,10 *	1-6	H01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07 MAY 1992	DAMAN M.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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